Collective foraging behavior in the larvae of the butterfly *Eurema blanda* (Lepidoptera, Pieridae)

Yoshiomi KATO* and Fumihito SAKAKURA

Department of Biology, International Christian University, Osawa, Mitaka, Tokyo, 181-8585 Japan

Abstract Foraging behavior of aggregating larvae in the pierid butterfly *Eurema blanda* was examined in laboratory conditions. Aggregates consisting of 13 to 17 larvae were successively observed from newly hatching to early 5th instar on the potted food plants. The aggregating larvae moved away from the site where all or most of food leaves were consumed, and then re-aggregated to a new site nearby one or two days later. During migration, the larvae moved individually. Although some larvae temporarily lost their way, they finally arrived at a new feeding site. Further, some larvae frequently used the same route during foraging, suggesting that some signals such as silk thread and/or pheromone deposited by the preceding larvae are used.

Key words *Eurema blanda*, butterfly, larval aggregation, foraging behavior, egg cluster.

Introduction

For the function of larval aggregation in lepidopteran insects, several hypotheses are presented (Fitzgerald, 1993): feeding facilitation, defense against predators and parasitoids, aposematism and thermoregulation. Fitzgerald (1993) also classified the foraging patterns in aggregating larvae into three types: patch-restricted, nomadic and central-directed. In the patch-restricted and central-directed types, aggregating larvae make a silken shelter or pad on the branch or leaves of a host plant, while in the nomadic type the aggregating larvae do not make a silken shelter, and frequently move from one feeding site to another site.

Behavioral and physiological mechanisms for formation and maintenance of larval aggregation through development vary among species. As signals responsible for the formation and maintenance of larval aggregation, a silken trail, pheromone substance, and physical contact among the larvae have been reported in moths and butterflies (Fitzgerald, 1993; Underwood and Shapiro, 1999; Fitzgerald and Pescador-Rubio, 2002; Fitzgerald, 2003).

Eurema blanda inhabits forests from tropical to subtropical regions of South-East Asia, and is a serious pest of Albizia trees in Indonesian plantations due to collective larval feeding (Irianto *et al.*, 1997). In Japan, *E. blanda* is distributed in subtropical South-western Islands. The females deposit eggs in cluster on leaves of Fabaceae plants (*Caesalpina globulorum*, *C. nuga*, *Cassia surattensis* and so on), and the larvae continue to aggregate from hatching till pupation. Several observations and experiments on egg clustering and larval aggregation of this species showed that aggregating larvae do not make silken shelters and move from feeding sites to new ones after consuming the leaves where they rest (Tanaka, 1975; Kato and Sakakura, 1994; Kato and Nishida, 1994; Sakakibara, 2004). However, whether the larval aggregates are kept even during their moving or reformed at the new site after temporary dispersal still remains unclear.

We here observed the foraging pattern of the larvae in laboratory conditions, and discuss

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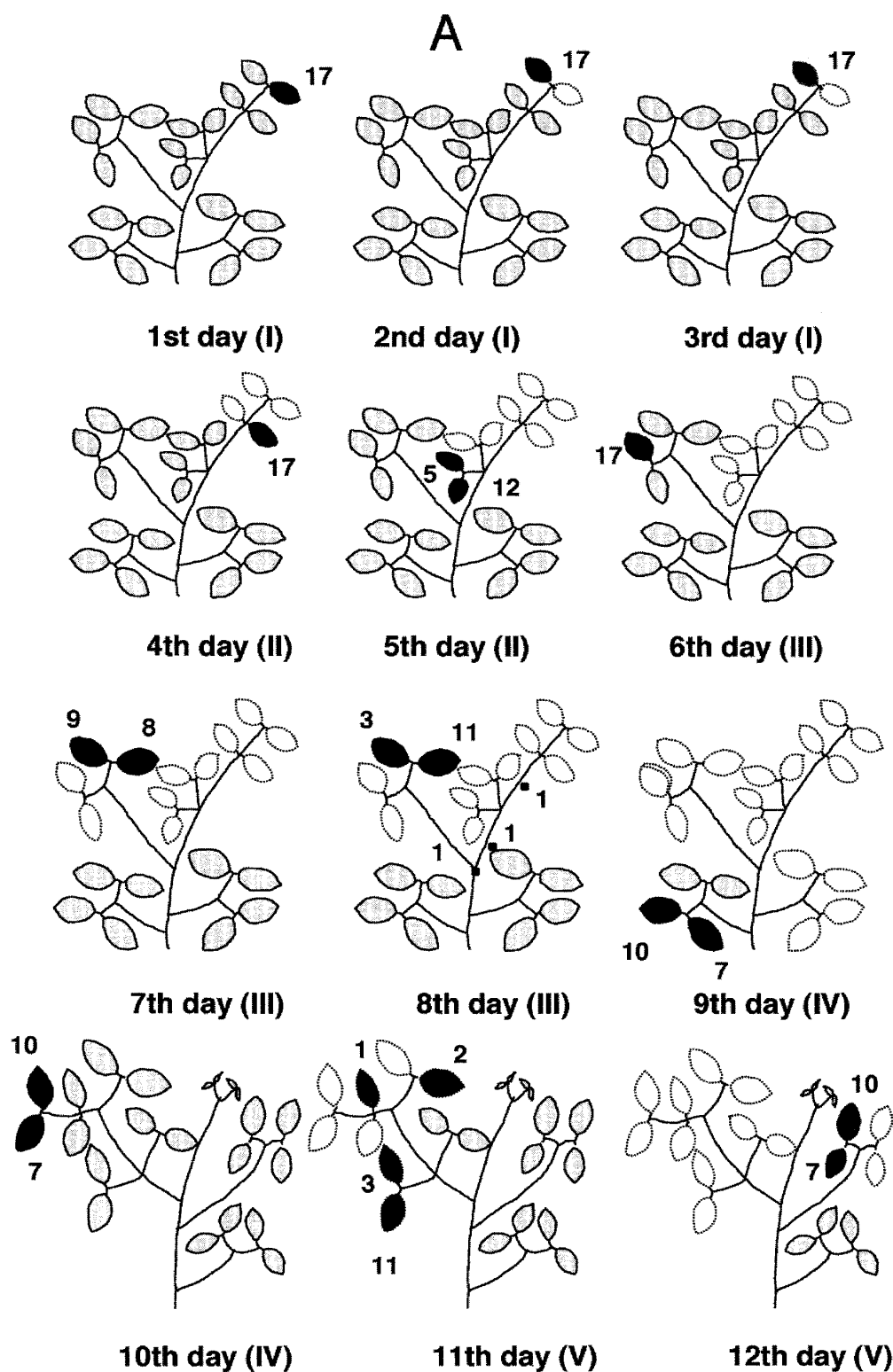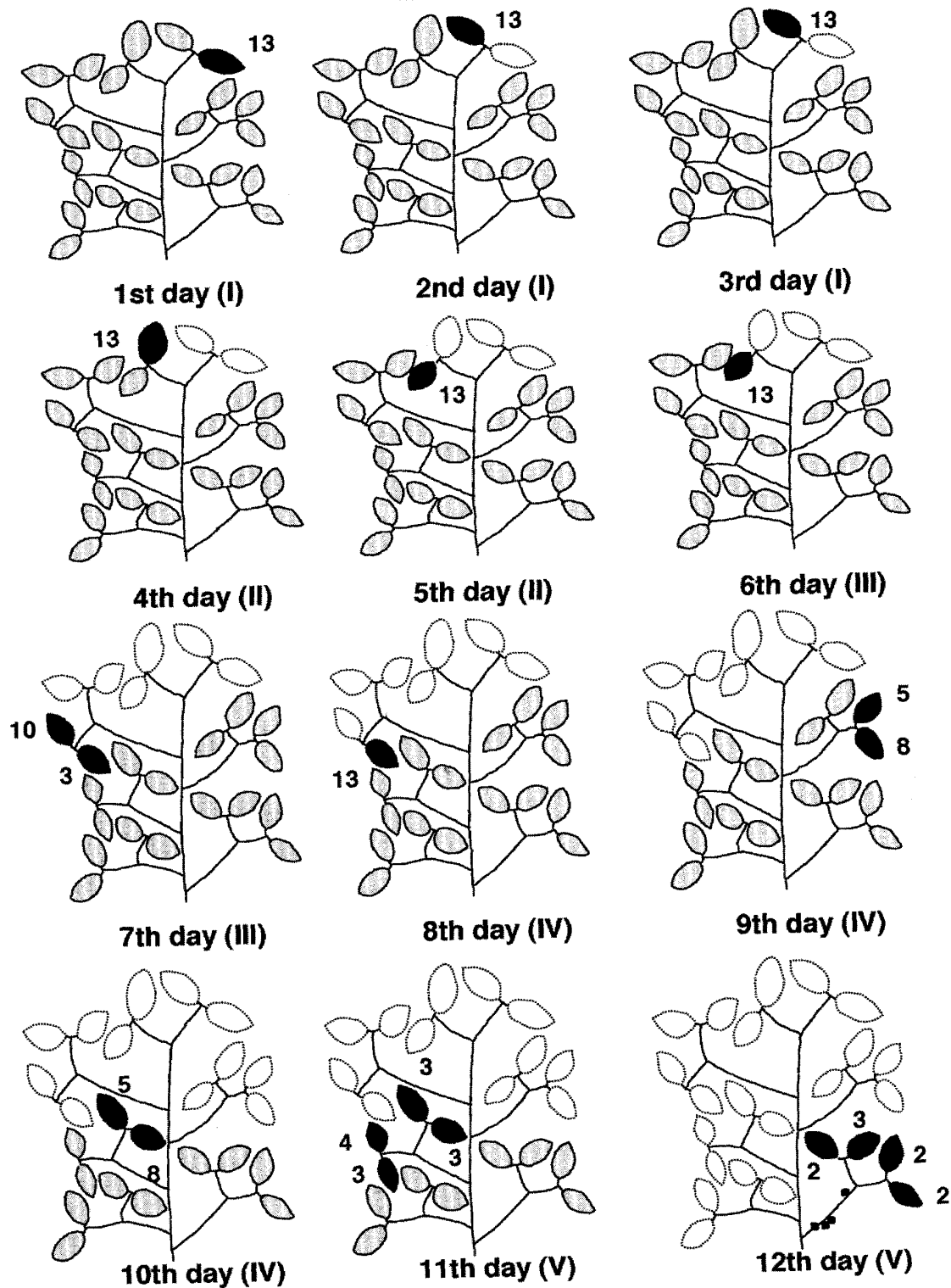*Corresponding author: kato@icu.ac.jp

A

Fig. 1. Daily changes in the position of larval aggregates of *Eurema blanda* on the host plant. A: Experiment 1. B: Experiment 2. Closed leaflet: the leaflet where larval aggregates were seen. Dotted leaflet: the area consumed by the larvae. Numerals on the plant show the number of larvae aggregating at a leaflet. Small round dots show single larvae. Roman numerals in parentheses show instar number.

B

1st day (I)

2nd day (I)

3rd day (I)

13

13

13

4th day (II)

5th day (II)

6th day (III)

13

13

13

5

8

7th day (III)

8th day (IV)

9th day (IV)

10

3

13

5

8

10th day (IV)

11th day (V)

12th day (V)

5

8

3

4

3

3

3

2

2

2

the formation and maintenance of the larval aggregation in this species.

Materials and methods

Wild females were caught in the fields of Ishigaki-jima and Iriomote-jima islands, and their offspring were maintained in the laboratory (Kato and Sakakura, 1994). Mated females were allowed to oviposit on leaves of *C. surattensis* in plastic cups (Kato and Nishida, 1994).

Experiments were carried out in the laboratory from early September to middle October. Room temperature during this season ranged from 30°C to 21°C. Potted seedlings of *C. nuga* of approximately 25–30 cm in height were prepared. Each egg-cluster obtained was fixed on a leaflet of the seedling with an insect pin. Egg clusters of relatively small size were prepared based on the size of host-plant used. Such sizes of egg cluster are also found in the field (Kato and Nishida, 1994).

After hatching, locations of the larval aggregates on the plant and the leaflets that had been consumed were recorded everyday till the beginning of 5th instar. When plant leaves were almost consumed, leaflets with the larval aggregates ware transferred to a new plant. Successive processes of larvae moving to a new site were also observed in 3rd instars with a video-camera (Hi8, Sonny).

Results

Daily changes in the position of a larval aggregate on the host plant during development

Experiments were carried out twice. In the first experiment (Fig. 1A), on the day of larval hatching, collective 1st instar larvae (N=17) began to feed on a leaflet following the consumption of egg-shells (Fig. 2A). On the next day, larvae were found on a leaflet on the opposite site after the consumption of the underside of the leaflet where they stayed. On the 3rd day all larvae entered into the moulting stage. On the 4th day, all larvae, which had ecdysed into 2nd instar, moved to a lower leaflet after the consumption of two leaflets. After temporary splitting of the aggregate, 3rd instar larvae were found aggregating into one group on a leaflet of another twig after feeding on some leaflets on the following day. During the 3rd instar, the aggregate was divided into two subgroups and the feeding continued. On the 8th day, the aggregate of 4th instar larvae was found split into two groups and
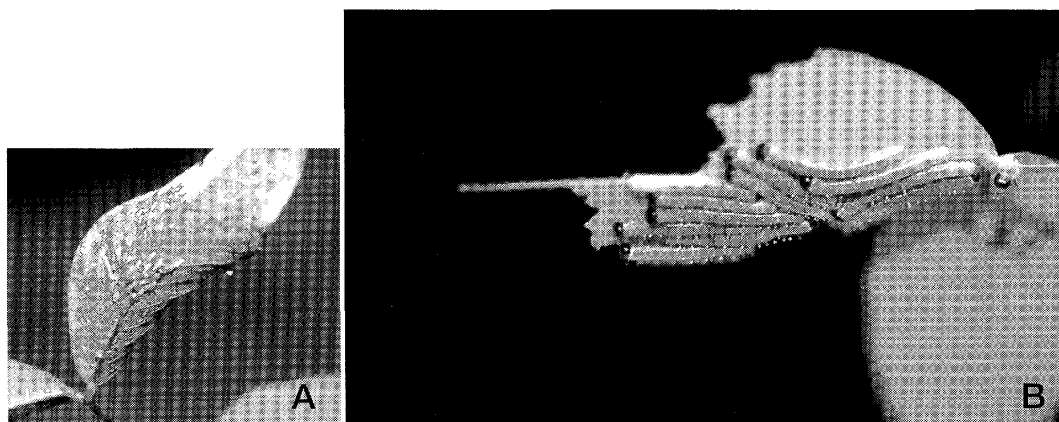

Fig. 2. Larval aggregates of *Eurema blanda* on the host plant. A: 1st instar larvae. B: 4th instar larvae.
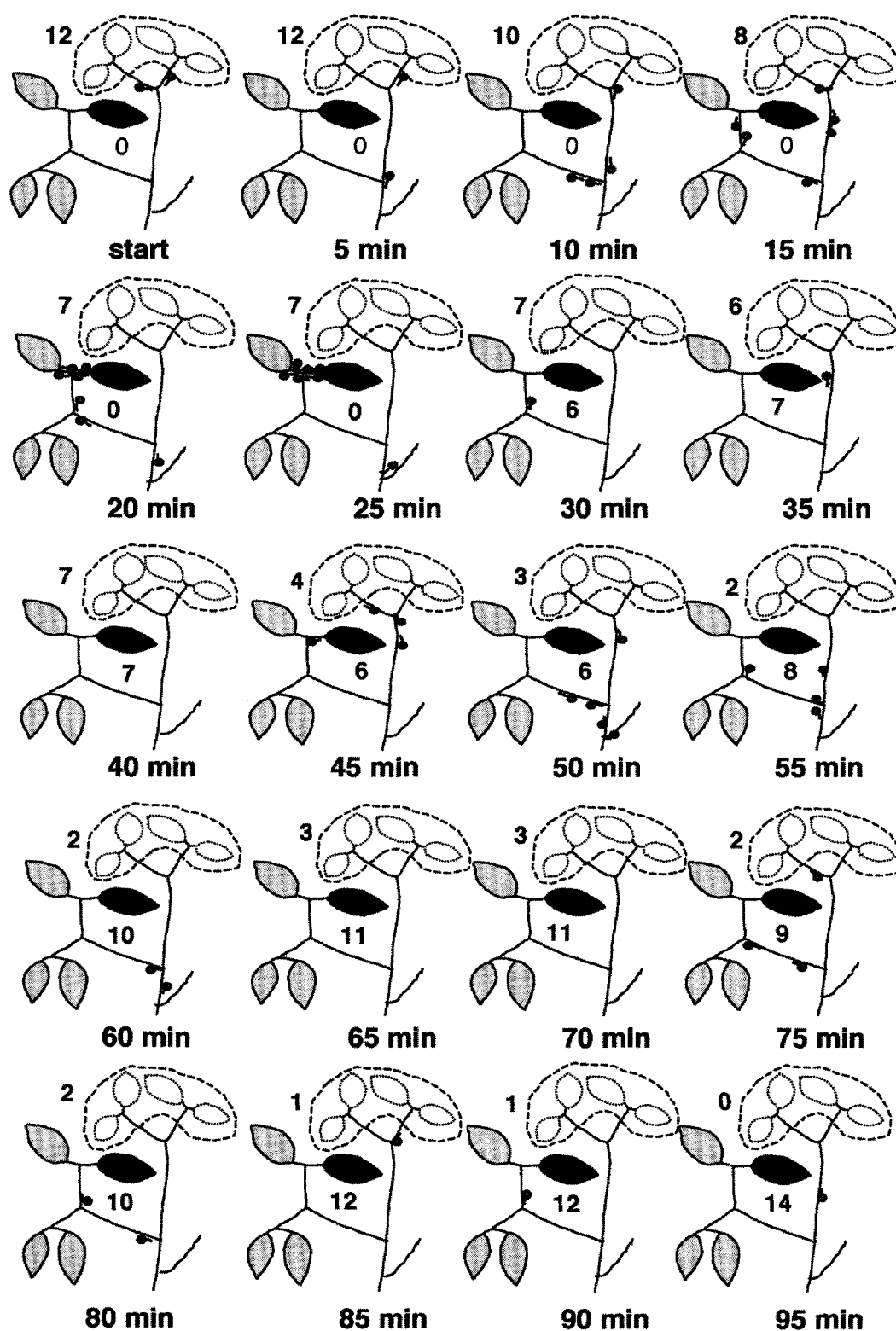
Fig. 3. Larval migration and its time course from the consumed area (dotted line) to a new site (closed leaflet) by 3rd instar larvae at 5 min intervals. Tadpole-like markings show single larvae. For other explanations, see Fig. 1.
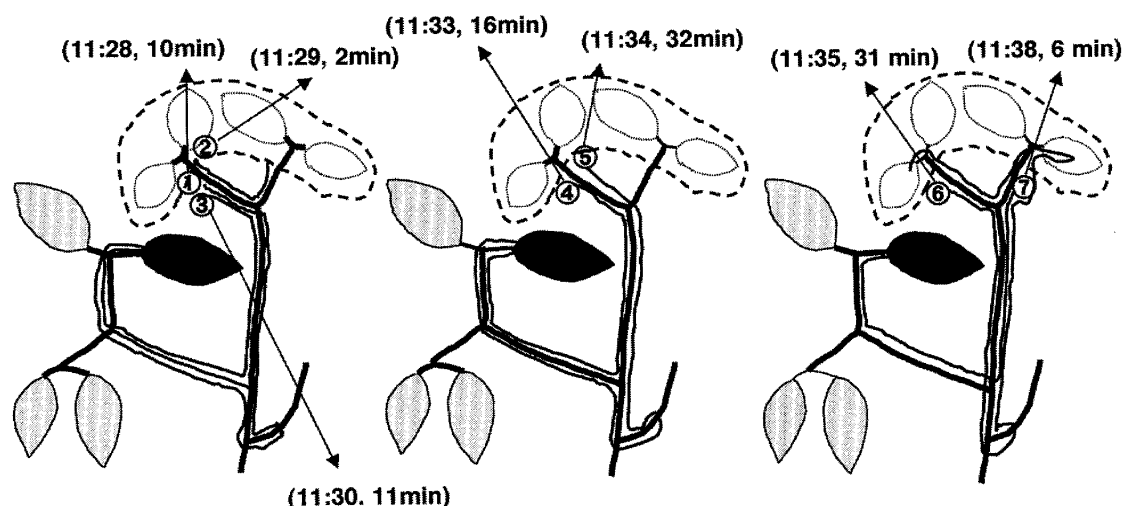
Fig. 4. Larval trails along which larvae (nos 1 to 7) moved to a new or original site. Time at which larvae started and time of period till arrival to a new or original site are indicated in the parentheses. For other explanations, see Fig. 1.

three single larvae. On the 9th day, larvae were divided into two subgroups and moulted into 4th instar (Fig. 2B). On this day, two leaflets on which two aggregates stayed were cut off, and then attached on the top of another twig because most leaves were consumed. On the 10th day, the larval aggregate was split into three subgroups and one single individual. On the 11th day, all larvae moulted into 5th instar and two subgroups were formed.

The results of the second experiment are shown in Fig. 1B, temporary changes in the position of the aggregating larvae were similar to those in the first experiment. From the day of hatching to the 6th day, the larval aggregate consisting of thirteen larvae remained in one group. They ate one leaflet on which they themselves were staying and repeatedly moved to a new site. Although the aggregate of 3rd instars was divided into two subgroups on the 7th day, these two subgroups were fused into one group where all larvae were of the 4th instar. Thereafter, the aggregate was again divided into two subgroups. On the 11th day, the larvae moulted into 5th instar and then the aggregate was split into more and smaller groups. In both experiments, the number of leaflets eaten per day increased with larval growth.

Migration mode by early instar larvae on the host plants

Using a separate larval aggregate, a third experiment was carried out. In most cases, aggregating larvae started to move to a new feeding site, and then ate food and rested in groups during the night period. However one aggregate of 3rd instar larvae ($N=14$) observed began to move around at 10:45 a.m. Fig. 3 shows the temporary process in which the larvae moved away from the site of four leaflets consumed (dotted area) and then reformed an aggregate at a new leaflet (closed area). Although each larva was not marked here, the larvae moved individually and did not behave in groups. It took about 95 min from the larval leaving till the reformation of the aggregate at the new site.

Trails along which larvae moved to a new site

During the above experiment 3, movements of several larvae were recorded. The routes where the larvae moved to a new feeding site are shown in Fig. 4. Five out of seven larvae observed successfully reached a new site and it took 6–32 min, while two larvae lost their

way, but finally arrived at the new site (data not shown). Most of them frequently used the same trail, and turned back at the same point.

Discussion

The present results demonstrated that the foraging behavior of *E. blanda* larvae is of nomadic type (Fitzgerald, 1993) and that the aggregating larvae move away from the one site where all or most of food leaves were consumed and then re-aggregate at a new feeding site. During moving, the larvae behaved individually, but not as a group. In general, it is known that gregarious larvae move in groups to a new feeding site (Long, 1955; Bush, 1969; Stamp, 1984). Larvae of the neotropical saturniid *Hylesia lineata* also form a long, head-tail procession during moving (Fitzgerald and Pescador-Rubio, 2002). Thus, it is worth examining whether such single moving behavior between two sites is usual or not in *E. blanda*.

In many gregarious species of moths and butterflies, larval foraging behavior is based on the silk trails deposited by the larvae (Long, 1955; Bush, 1969; Stamp, 1984). Although the silk trails seem to act as a tactile stimulus among foraging individuals, it has been reported that some species use chemical pheromones as trail markers (Fitzgerald and Edgerly, 1982; Underwood and Shapiro, 1999, Fitzgerald, 2003). We observed that some larvae arrived smoothly at the new site frequently using the same route whereas although other larvae lost their way, they finally gathered at the new site. This suggests that some signals such as silk thread and/or pheromone deposited by the preceding larvae may be adopted during moving. Further investigation is needed to test this idea.

References

Bush, G. L., 1969. Trail laying by larvae of *Chlosyne lacinia*. *Ann. ent. Soc. Am.* **62**: 674–675.

Fitzgerald, T. D., 1993. Sociality in caterpillars. *In* Stamp, N. E. and T. M. Cassey (Eds), Caterpillars: *Ecological and evolutionary Constraints on foraging*: 372–403. Chapman and Hall, New York.

————, 2003. Role of trail pheromone in foraging and processionary behavior of pine processionary caterpillars T*haumetopoea pityocampa*. *J. chem. Ecol.* **29**: 513–532.

Fitzgerald, T. D. and J. S. Edgerly, 1979. Specificity of trail markers of forest and eastern tent caterpillars. *J. chem. Ecol.* **5**: 564–574.

Fitzgerald, T. D. and A. Pescador-Rubio, 2002. The role of tactile and chemical stimuli in the formation and maintenance of the processions of the social caterpillar *Hylesia lineata* (Lepidoptera: Saturniidae). *J. Insect Behav.* **15**: 659–674.

Irianto, R. S. B., Matsumoto, K. and K. Mulyadi, 1997. The yellow butterfly species of the genus *Eurema* Hübner causing severe defolation in the forestry plantations of albizzia, *Paraserianthes falcataria* (L.) Nielsen, in the western part of Indonesia. *JIRCAS J.* (4): 41–49.

Kato, Y. and N. Nishida, 1994. Egg-cluster laying in the pierid butterfly, *Eurema blanda* (Boisduval). *Tyô Ga* **45**: 71–78.

Kato, Y. and F. Sakakura, 1994. Artificial diet rearing of *Eurema blanda* and some notes on its host-plant. *Tyô Ga* 45: 21–26 (in Japanese with English summary).

Long, D. B., 1955. Observations on subsocial behaviour in two species of lepidoptera. *Trans. R. ent. Soc. Lond.* **106**: 421–437.

Sakakibara, M. 2004. How and why does *Eurema blanda arsakia* (Fruhstorfer) (Lepidoptera: Pieridae) pupate in groups? *Jap. J. Ent.* (N. S.) **7**: 73–78 (in Japanese with English summary).

Stamp, N. E., 1984. Foraging behavior of tawny emperor caterpillars (Nymphalidae: *Asterocampa clyton*). *J. Res. Soc.* **38**: 186–191.

Tanaka, B., 1975. Some observations on *Eurema blanda arsakia* Fruhstorfer (Lepidoptera: Pieridae) in Iriomote Is. *Tyô Ga* **26**: 67–78 (in Japanese).

Underwood, D. L. A. and A. M. Shapiro, 1999. Evidence for division of labor in the social caterpillar *Eucheira socialis* (Lepidoptera: Pieridae). *Behav. Ecol. Sociobiol.* **46**: 228–236.

摘　　　要

タイワンキチョウ幼虫の集合的採餌行動 (加藤義臣・坂倉文人)

タイワンキチョウは日本では八重山諸島に生息し，ハスノミカズラやナンテンカズラなどのマメ科植物を寄主としている．雌成虫は寄主植物上に卵塊で産卵し，幼虫も蛹化にいたるまで集団で生活する．本研究においては，この幼虫の集合的採餌行動を，鉢植えにしたナンテンカズラ実生を使って実験室内において調べた．実験には13–17頭の比較的小集団の幼虫を用いて，孵化から5齢初めまでの集団の移り変わりを毎日観察した．幼虫集団は葉を食い尽くすと移動し，近くの新しい葉に再び集合した．3齢の場合に，この移動から再集合までにほぼ1時間半を要した．観察した限りでは，幼虫は単独で移動し，集団での移動はみられなかった．移動幼虫は新しい場所に達する過程には，しばしば先行した幼虫と同じルートを使ったことから，幼虫が移動の際には何らかの道しるべ (糸の道とかフェロモン) を使っていることが示唆される.